# A Beach Probing System (BPS) for Determining Surf Zone Bathymetry, Currents, and Wave Heights from Measurements Offshore


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## LONG-TERM GOAL

The goal of this project is to investigate the feasibility of using offshore measurements of the surface gravity wave field to remotely sense the inshore environment (hydrography, currents, and breakers).

## OBJECTIVES

- To develop a data assimilation method (BPS Model) for estimating the nearshore (shoreline to nominally 500m offshore) depth and alongshore-directed current profiles using offshore infragravity wave measurements.

- To develop a self-powered, self-recording, GPS-clock-accurate Sensor Package suite of three-axis current, pressure, and orientation sensors integrated into a semi-automated, near-real-time data acquisition, quality control, and analysis system for measurements of:

    - wind waves (0.04 - 0.35 Hz) and

    - infragravity waves (0.001 - 0.04 Hz).

- To test and evaluate the BPS Model with both simulated and field (collected by the new sensor packages) data.

## APPROACH

This is the end of the fifth year of an extended six-year program of concurrent development of the BPS Model, the Sensor Package suite, and the data acquisition and analysis system. Field data collected at the beginning of the fourth year (Fall 1998 at Duck, NC), using the BPS Sensor Packages, compliments simulation data in the development and testing of the BPS Model. Several field tests of the BPS hardware and software system have taken place on a local Washington beach (Copalis, WA; August 1997, April 1998, and May 2000). The latest effort tested the final design of the BPS hardware and software - an autonomous instrument package with the ability to up- and download software/data using a hand-held device referred to as the Dr. Box. Two optional experiments, one to demonstrate the real-time processing and the other to investigate the ubiquity of infragravity waves on different beach genotypes, have not been activated.

The basic premise of the BPS modeling and data assimilation approach is as follows:

- Acquire data from an in-situ phase array of five to seven Sensor Packages offshore of the surf zone to directly measure the wind wave and infragravity wave directional spectra,

- Apply inverse methods, and other data assimilation techniques, to estimate inshore of the array,

    - surf-zone depth profile (hydrography)

    - surf-zone alongshore current profile (magnitude and direction)

- Data fusion of the wind wave and infragravity wave spectral information with further modeling (beyond the redefined scope of this program) provides estimates of,

    - wave breaker-height and type (spilling, plunging, collapsing)

    - surf-zone width.

This project is multi-faceted and, as such, requires a breadth of knowledge and experience. Key personnel on this project from NorthWest Research Associates, Inc. are: Joan Oltman-Shay (a nearshore oceanographer, field experimentalist, and data analyst), Jim Secan (an ionospheric physicist, system software developer, and inverse modeler), Frank Smith (an electronics design engineer), Skip Echert (a field experimentalist), and Uday Putrevu (a nearshore theoretician and modeler). Key personnel consulting on this project are: John Booker (a geophysicist and inverse modeler from Univ. of Washington), Ed Boss (a system software developer from Sigma Solutions), Bob Bussey (a system software developer from Eagle Harbor Software), and Michael Clifton (a field logistic expert from Scripps Inst. of Oceanography, SIO). In addition, there is an advisory panel whose members were chosen to both advise on the technical approach of the project and on directions that may better serve the Navy if this technology was to transition. The members are: Barry Blumenthal (ONR), Dan Crute (CSS), Bob Guza (SIO), Rob Holman (OSU), James Kaihatu (NRL-SSC), Steve Payne (SPAWAR), and Ed Thornton (NPGS).

## WORK COMPLETED

We have successfully completed the following tasks in FY2000:

- BPS (Inverse) Model design and testing with simulation data (Putrevu et al, AGU, 1999; Putrevu et al., JGR Oceans, 2000);

- Sensor Package and software design modification for autonomous deployment with Sensor Package software and data up/download capability via a hand-held device (Boss and Oltman-Shay, Sea Technology, 2000);

- A 5-day-long field test at Copalis beach, Washington (north of Gray's Harbor; May 2000) for testing of the autonomous system design;

- Comparison of surf zone data collected with a Nortek Vector Velocimeter and a Sontek ADVO (Gordon and Oltman-Shay, Aug 2000, http://www.nortekUSA.com/vector.html).

## RESULTS

### BPS Inverse Model (Putrevu et al, AGU, 1999; Putrevu et al., JGR Oceans, 2000)

An AGU Fall 1999 presentation and a JGR Oceans paper describe the amount of information (on the bathymetry and currents) contained in the edge wave dispersion relationship and the feasibility of using remote measurements of the edge wave dispersion relationship to deduce the nearshore bathymetry and currents. An inverse technique is presented and simulation data is used to test fidelity of the bathymetry and current variations deduced by the inversion. The main features of both the bathymetry and longshore currents are resolved well by the invesion. Specifically, the inversion accurately recovers the monotonic bathymetirc variantions. For barred beaches, the inversion recovers the bar but the crest of the bar tends to be slightly inshore of the true location (Figure 1). The inversion extracts the general features (direction, shape, etc.) of the longshore current distribution but tends to underestimate its maximum value and the shear on the seaward side (Figure 2). Overall, it is shown that the edge wave dispersion relationship contains a substantial amount of information about the underlying bathymetry and currents and that it is feasibile to extract this information using inverse techniques. The paper also discusses additional infragravity wave meausreents that may be used to improve the fidelilty of the inversions.

### Sensor Package Design and Tests (Boss and Oltman-Shay, 2000)

The Sensor Package is designed to be an element in a high-resolution phase-array used to measure the wind and infragravity directional spectra. Each Sensor Package contains: a Sontek ADVO (3-component Acoustic Doppler Velocimeter), a Setra 270 pressure sensor, a Precision Navigation TCM2 compass/inclinometer, an Onset Tattletale 8 (TT8) data logger/controller, a OAK 579 10 MHz Oven-Controlled Crystal Oscillator (OCXO), a Persistor 80MB flash memory card (>30 days of data), 27 alkaline D cells (4+ days of power, extended to 1month power with external battery pack), an external port for power, communication, and synchronization, and an external port for an externally mounted sensor (e.g., temperature/conductivity sensor, altimeter, other). The Sensor Package is designed to operate both autonomously and with cabled data communication and power to shore.

In the original cable configuration, Sensor Packages were cabled to an onshore computer called the Array Controller. It consisted of a desktop PC running Windows 95. Add-on cards included an 8 port Digiboard serial IO card, a Digital Research digital IO board, and a TrueTime GPS receiver board. The Array Controller was designed to be capable of receiving data from eight Sensor Packages and issuing commands to each Sensor Package to reset the time of day, check the clock drift, and to synchronize data buffer start times. The Array Controller repacked the data from all available Sensor Pacakges and passed the data along to the Onshore Processor for analysis and archival.

In the autonomous configuration, we moved the functionality of the Array Controller into a special purpose portable computer, dubbed the "Doctor Box". We extended the functionality of the Doctor Box to allow it to also retrieve or "upload" data resident on flash memory of the Sensor Packages. We designed the Doctor Box to be small and easily transportable; a short length of underwater cable connected the Doctor Box to a Sensor Package. This new configuration eliminated the Array Controller and the hundreds of meters of cable between Sensor Packages and the Array Controller.

**Copalis Beach, WA Field Test (May 2000)**

The May 2000 Copalis field effort was designed to test the most recent Sensor Package design - an autonomous Sensor Package with data up/down load capability via the "Dr. Box." A small array of Sensor Packages (five) were deployed for 4 days for this purpose.

The Sensor Packages were deployed at low tide and acquired data at high tide with 2.5m of water covering the Sensor Packages. The beach is low-sloping (1:60) and dissipative; the observed wind wave field was always saturated. A longshore current in 3m depth of 30cm/sec was typically observed. The autonomous operation worked well; a few bugs were found; most bugs were corrected in the field with the remainder corrected upon return to the lab. The test has given us the confidence we need to use this new design in a scientific experiment. Five of the sixteen Sensor Packages have been modified with this latest version of the BPS Sensor Pacakge design. Modifications to the remaining Sensor Packages will be made when these packages are required for a scientific experiment.

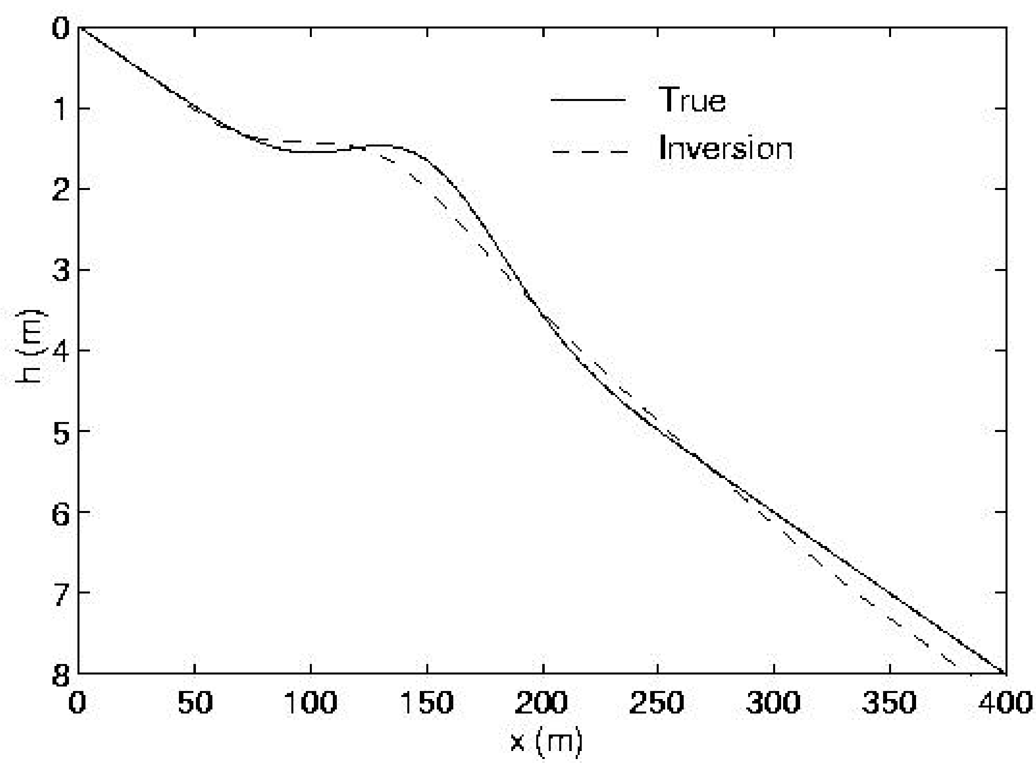


***Figure 1. BPS Model Inversion of a synthetic edge-wave wavenumber-frequency spectrum simulating noisey linear-array measurements taken in 5m depth, 250 m offshore on the True depth profile [h(x)].***

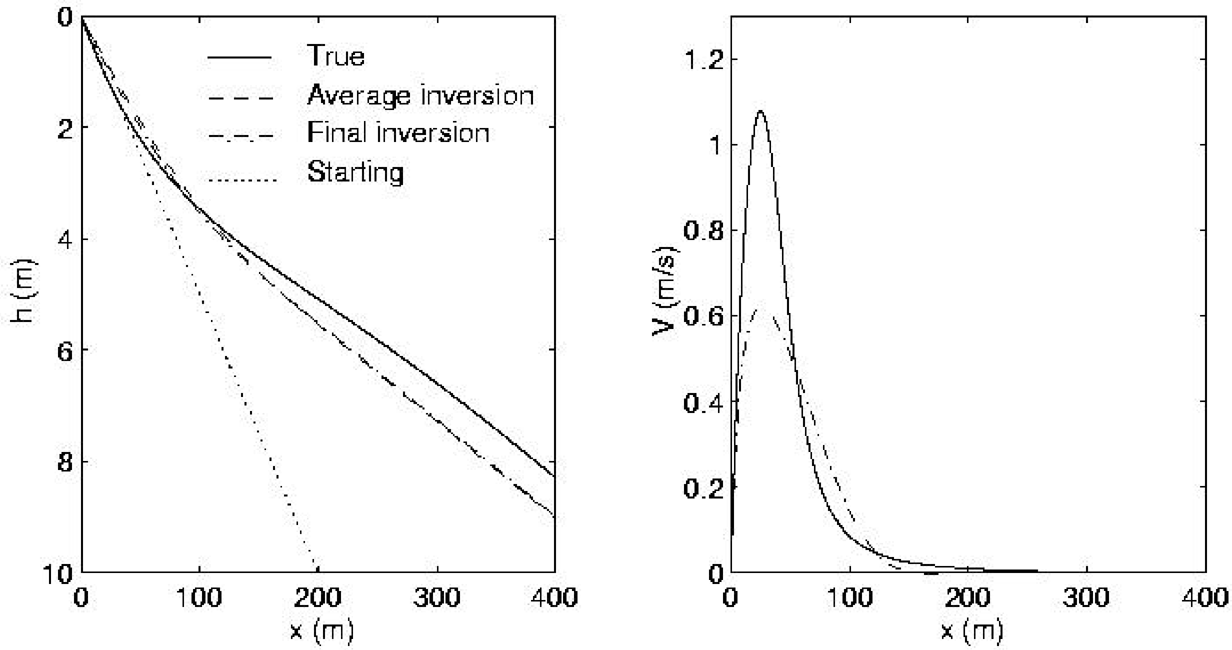


***Figure 2. BPS Model Inversion simulating measurements taken in 5m depth, 250 m offshore on the True depth profile [h(x)]. Left panel: inversion for depth profile; right panel: inversion for alongshore current profile (solid - True V(x), dashed - Final inversion). The inversion was started with a planar depth profile (dotted) and zero mean alongshore current. The Average Inversion for the depth profile is an intermediate step, before the model inverts for alongshore current.***

**Comparison of surf zone data collected by two types of Acoustic Doppler Velocimeters (Gordon and Oltman-Shay, Aug 2000, www.nortekUSA.com/vector.html)**

Data were collected with a Nortek Vector Velocimeter (Vector) and a Sontek ADVO, both Acoustic Doppler Velocimeters, during the Copalis Beach May 2000 field test of the BPS Sensor Packages. Both instruments were partially buried in the sand, separated by 2m alongshore. The ADVO collected data at 2, 4, and 8 Hz with a maximum velocity set at 2m/s; the Vector collected data at 8 Hz with a maximum velocity set at 1m/s. Comparisons of 8Hz data show the Vector and ADVO producing nearly identical spectra over most of the frequency band; below 0.5 Hz, the data are highly coherent (>0.95) and in phase. The ADVO data appear to reach a noise floor near $10^{-4}$ $m^2/s^2$Hz (with the 2m/sec dynamic range), the Vector spectra fall as low as $3x10^{-5}$ $m^2/s^2$Hz without appearing to reach a noise floor (with the 1m/sec dynamic range). Overall, this test lent confidence and credibility to the measurements from both instruments.

## IMPACT/APPLICATION

Sixteen Sensor Packages, two automated data acquisition, quality control and analysis systems, and two Dr Boxes have been designed, developed, and tested. This field system is designed for acquisition of wave and current data in the harsh environment of the nearshore (1m to 10m depth). The Sensor Packages can be deployed autonomously (self-powered and recording) or cabled to shore. In either mode, the accurate on-board clock in each package insures synchronous data acquisition between packages and other instrumentation.

The potential application of the BPS model is broader than the long-term goal of measuring surf zone environmental conditions from measurements offshore. For instance, an unexpected application of the model for scientists is the estimation of the cross-shore profile of alongshore-directed current from an alongshore-aligned array of sensors. The estimation of alongshore-current profiles can come in handy in cases where deployment of a cross-shore array of sensors is prohibitive, either due to the expense or because of logistical difficulties.

Another potential benefit of the BPS model will be its application in the study of edge wave mode mix. A fundamental question about edge wave dynamics is the relative amounts of modal energy. This knowledge is important to the predictive modeling of these waves (generation and dissipation). The BPS model lays the foundation for the type of model/data analysis that is required to answer this question.

## TRANSITIONS

Because the Sensor Packages are autonomous, they are attractive tools for large-scale surf zone studies where cable to shore would be prohibitive (both cost and logistics). These instruments have been proposed for use in other nearshore field efforts.

## PUBLICATIONS

Boss, Ed, J. Oltman-Shay, accepted: An autonomous phase-array for wave and current measurements in the nearshore of an open-coast beach, Sea Technology.

Gordon, Lee, J. Oltman-Shay, Aug 2000: Surf zone observations with a Nortek Vector Velocimeter and a Sontek ADVO, www.nortekUSA.com/vector.html.

Putrevu, U., J. Booker, J. Oltman-Shay, M. Pruis, and M. Horgan, 1999: Inverting edge wave measurements to deduce beach topography and longshore currents, AGU Fall Abstracts.

Putrevu, U., J. Booker, J. Oltman-Shay, M. Pruis, 2000 (submitted): Inverting edge-wave measurements to determine nearshore bathymetry and longshore currents. Part I - Theory and tests, JGR Oceans.